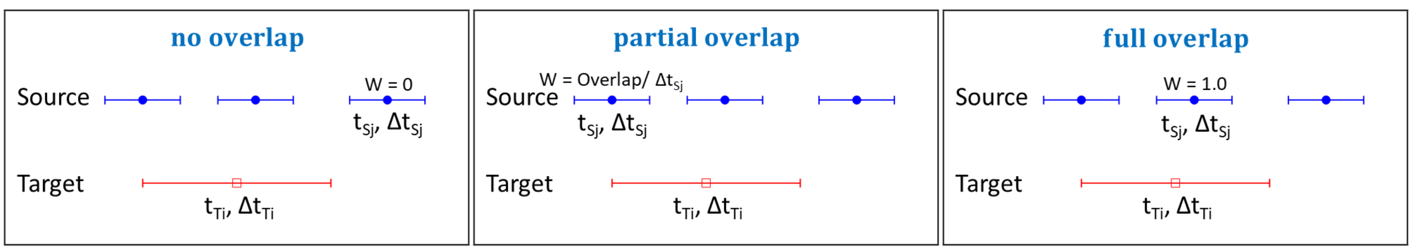
Online Merge Tool

The measurement data from different instruments often have different sampling time stamps and/or integration times. The SSD-AC Online Merge Tool is designed to put various in-situ measurement data from a common platform to a common sampling time base. This is implemented using weighted time averages of different source data, i.e., individual measurement data, onto to the target (common) time base. The target time base can be a continuous time with a constant interval or the time base of an individual measurement. The weighting factor calculation is based on the overlap between a source sampling time interval and the target time interval or merge time interval (see figure below). The Online Merge Tool can also evaluate the weighted standard deviation of individual measurements within each target time interval as well as the number of source data points. This tool can also handle vector averages and propagate precision uncertainty using weighted quadrature average method. The online merge tool requires data to be reported in ICARTT 1.1 or 2.0 format as it interprets the missing/LOD data codes embedded in the headers. The users need to specify the variable type so the tool will handle the data properly. This document outlines how the weighting factor is assessed and how different types of the variables are merged.

1. Weighting Factor

The weighting factor is calculated for each target time interval and source data point involved in the merge. The value of the weighting factor for a source data point is determined by the overlap between the source interval and the target interval, see Figure below.



Here the Source sampling time base refers to the center (t_{Sj}) and period (Δt_{Sj}) of the sampling time for a given source data point. The target (merge) time base is defined by the center and interval, i.e., t_{Ti} and Δt_{Ti} respectively.

The weighting factor for the j^{th} source data point and the i^{th} target time interval, $w_{j,i}$, is calculated as follows:

$$w_{j,i} = \begin{cases} 0 & if\ |t_{Ti} - t_{Sj}| \geq \dfrac{(\Delta t_{Ti} + \Delta t_{Sj})}{2} \\ \dfrac{\dfrac{(\Delta t_{Ti} + \Delta t_{Sj})}{2} - |t_{Ti} - t_{Sj}|}{\Delta t_{Sj}} & \left|\dfrac{\Delta t_{Ti} - \Delta t_{Sj}}{2}\right| < |t_{Ti} - t_{Sj}| < \dfrac{(\Delta t_{Ti} + \Delta t_{Sj})}{2} \\ 1 & if\ |t_{Ti} - t_{Sj}| \leq \left|\dfrac{\Delta t_{Ti} - \Delta t_{Sj}}{2}\right| \end{cases} \quad (1)$$

where: t_{Sj} = Source interval midpoint; Δt_{Sj} = Source interval duration; t_{Ti} = Target interval midpoint; Δt_{Ti} = Target interval duration; i = Target interval; and j = Source interval.

It is noted that equation (1) applies regardless if Δt_{Ti} is larger than Δt_{Sj} or not. This reflects that equation (2) is symmetric with respect to the target variable and source variables.

The total weighting factor for a target interval, w_i, is calculated as follows:

$$w_i = \sum_{j=1}^{n} w_{j,i} \qquad (2)$$

where n is the number of source data points.

2. Scalars

$$x_{Ti} \frac{\sum_{j=1}^{n} w_{j,i} x_{Sj}}{w_i} \qquad (3)$$

Equation 3: Weighted average of scalar variable data for the i^{th} target interval, x_{Ti}, where x_{Sj} is the Source data value for the j^{th} point.

$$S_{Ti} = \sqrt{\frac{\left(\left(\sum_{j=1}^{n} w_{j,i} x_{Sj}^2\right) - w_i x_{Ti}^2\right) w_i}{w_i \times w_i - \sum_{j=1}^{n} w_{j,i} \times w_{j,i}}} \qquad (4)$$

Equation 4: Weighted standard deviation (variation/dispersion from the average) for scalar variables for the i^{th} target interval.

$$SigPre_{Ti} = \frac{\sqrt{\sum_{j=1}^{n} w_{j,i} \times SigPre_{Sj}^2}}{w_i} \qquad (5)$$

Equation 5: Propagated precision using weighted quadrature average, where $SigPre_{Sj}$ is the j^{th} point of a source data precision variable.

3. Vectors

Vector variable, *v*, averaging is done using *x* and *y* components.

$$v_{x,Sj} = \cos\left(v_{Sj} \times \frac{\pi}{180}\right) \qquad (6a)$$

$$v_{y,Sj} = \sin\left(v_{Sj} \times \frac{\pi}{180}\right) \qquad (6b)$$

Equation 6a and 6b: *x* and *y* components of the j^{th} vector data point. Vector variables are assumed to be in degrees from 0 to 360, hence converting to radians.

$$v_{Ti} = \begin{cases} atan2(v_{y,i}, v_{x,i}) \dfrac{180}{\pi} & if\ atan2(v_{y,i}, v_{x,i}) \geq 0 \\ atan2(v_{y,i}, v_{x,i}) \dfrac{180}{\pi} + 360 & if\ atan2(v_{y,i}, v_{x,i}) < 0 \end{cases} \qquad (7)$$

$$\text{Where: } v_{y,i} = \frac{\sum_{j=1}^{n} w_{j,i} \times v_{y,Sj}}{w_i}, \quad v_{x,i} = \frac{\sum_{j=1}^{n} w_{j,i} \times v_{x,Sj}}{w_i}$$

Equation 7: The merged vector variable, v_{Ti}, converted back to degrees between 0 and 360. It is noted the atan2 function may behave differently in different programming languages. For example, $v_{y,i}$ and $v_{x,i}$ should be switched, i.e., atan2($v_{x,i}$, $v_{y,i}$), if equation (7) were applied in an Excel spreadsheet.

$$S_{x,i} = \sqrt{\frac{\left(\sum_{j=1}^{n} w_{j,i} \times v_{x,Sj}^2 - w_i v_{x,i}^2\right) w_i}{w_i^2 - \sum_{j=1}^{n} w_{j,i}^2}} \qquad (8a)$$

$$S_{y,i} = \sqrt{\frac{\left(\sum_{j=1}^{n} w_{j,i} \times v_{y,Sj}^2 - w_i v_{y,i}^2\right) w_i}{w_i^2 - \sum_{j=1}^{n} w_{j,i}^2}} \qquad (8b)$$

Equation 8: *x* and *y* components of the standard deviation for the i^{th} target interval.

$$\delta f = \frac{x\delta y + y\delta x}{x^2 + y^2} \qquad (9)$$

$$S_{Ti} = \frac{\left|\frac{v_{y,i}}{v_{x,i}}\right| \times \sqrt{\left(\frac{S_{x,i}}{v_{x,i}}\right)^2 + \left(\frac{S_{y,i}}{v_{y,i}}\right)^2}}{1 + \left(\frac{v_{y,i}}{v_{x,i}}\right)^2} \times \frac{180}{\pi} \qquad (10)$$

Equations 9: Error propagation of the arctangent used to recombine the *x* and *y* components of the standard deviation

Equation 10: The merged standard deviation

4. Wind

$$U_{Sj} = -1 \times spd_{Sj} \times \sin\left(\theta_{Sj} \times \frac{\pi}{180}\right) \qquad (11a)$$

$$V_{Sj} = -1 \times spd_{Sj} \times \cos\left(\theta_{Sj} \times \frac{\pi}{180}\right) \qquad (11b)$$

Equation 11a and 11b: Converting the j^{th} point of wind speed (spd_{Sj}) and direction (θ_{Sj}) to the east-west component, u_{Sj}, and north-south component v_{Sj}. It is assumed that wind direction is in degrees. The weighted average for vector components (U_i and V_i) are calculated via equation 3. The vector average of the wind speed can be constructed through quadrature sum of the u and v components.

$$\theta_i = 180 + \frac{180}{\pi} \times atan2(U_i, V_i) \qquad (12a)$$

$$\text{Where: } U_i = \frac{\sum_{j=1}^{n} w_{j,i} U_{Sj}}{w_i}, \quad V_i = \frac{\sum_{j=1}^{n} w_{j,i} V_{Sj}}{w_i} \qquad (12b)$$

Equation 12: Weighted average wind direction value for the i^{th} target interval. Equation (12a) is based on C++ and Python programming languages. One may switch U_i and V_i in the equation for different programming languages.

$$\theta_{v,i} = \frac{\sum_{j=1}^{n} w_{i,j} \cos\left(\theta_{Sj} \times \frac{\pi}{180}\right)}{w_i} \qquad (13a)$$

$$\theta_{u,i} = \frac{\sum_{j=1}^{n} w_{i,j} \sin\left(\theta_{Sj} \times \frac{\pi}{180}\right)}{w_i} \qquad (13b)$$

Equation 13: Weighted merge of the angle components.

$$S_{Ti} = \sin^{-1}\left[1 + \left(\frac{2}{\sqrt{3}} - 1\right)\varepsilon^3\right] \times \frac{180}{\pi} \qquad (14)$$

$$\text{where } \epsilon = \sqrt{1 - \left(\theta_{u,i}^2 + \theta_{v,i}^2\right)}$$

Equation 14: Yamartino method[1] for wind direction standard deviation.

5. Data flag handling

This feature is designed to handle data flags which designate either sampling locations, sampling events (e.g., fire plume), or sampling conditions (e.g., cloud conditions). These flags should not be averaged as it may yield misleading results. The online merge tool will give a binary output to indicate if there is a change in the data flag values within the target (merge) interval. The goal is to alert users to further investigate the data flag values in this case. The value of flag variables are restricted to be from 0 to 1E8.

$$xFlag_{Ti} = \begin{cases} xFlag_{Sj} & if\ xFlaf_{Sj} = contant\ when\ w_{j,i} > 0 \\ -6666 & if\ xFlaf_{Sj} \neq contant\ when\ w_{j,i} > 0 \end{cases} \qquad (15)$$

Equation 15: Data flag handing for flag variable, xFlag, where $xflags_{Sj}$ represent the j^{th} point of the source data value and $xFlag_{Ti}$ denotes the output for the i^{th} target interval. "-6666" is the indicator code for flag value changes.

6. Data code handling

The online merge tool handles ICARTT format missing data codes and limit of detection (LOD) codes.

6.1 Missing data code handling

The summation skips over missing data entries when it encounters one within a target interval. For example, equation (2) and (3), in practice, are modified as below:

[1] Yamartino, R.J. (1984). "A Comparison of Several "Single-Pass" Estimators of the Standard Deviation of Wind Direction". Journal of Climate and Applied Meteorology 23 (9): 1362-1366.

$$w_i = \sum_{j=1}^{n} w_{j,i} \quad if\ x_j \neq -9999 \quad (2')$$

$$x_i = \frac{\sum_{j=1}^{n} w_{j,i}\, x_j}{w_i} \quad if\ x_j \neq -9999 \quad (3')$$

where "-9999" is the missing data code. If no non-missing source data is encountered within a target interval, the output for that target interval is the missing data code.

6.2 Limit of detection code handling

The online merge tool outputs the same LOD code if one LOD code is encountered within a target interval.

$$x_i = \begin{cases} -8888 & if\ x_j = -8888\ when\ w_{j,i} > 0 \\ -7777 & if\ x_j = -7777\ when\ w_{j,i} > 0 \\ \dfrac{\sum_{j=1}^{n} w_{j,i}\, x_j}{w_i} & if\ x_j \neq -8888\ and\ x_j \neq -7777\ when\ w_{j,i} > 0 \end{cases} \quad (16)$$

where "-8888" represents the lower limit of detection and -7777 denotes the upper limit of detection. Cases where both upper and lower limit of detection codes are encountered in the same target interval are considered highly unlikely for commonly used merge time intervals and therefore treated in the same way as encountering just the lower limit of detection code (-8888) within the target interval.